Programming Languages

2nd edition

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Chapter 9
Functions

It is better to have 100 functions operate on one data structure than 10 functions on 10 data structures.

A. Perlis

Contents

9.1 Basic Terminology

- Value-returning functions:
  - *known as "non-void functions/methods" in C/C++/Java*
  - *called from within an expression.*

    e.g., x = (b*b - sqrt(4*a*c))/2*a

- Non-value-returning functions:
  - *known as "procedures" in Ada,*

    "subroutines" in Fortran,

    "void functions/methods" in C/C++/Java
  - *called from a separate statement.*

    e.g., strcpy(s1, s2);

9.2 Function Call and Return

Example C/C++ Program

Fig 9.1

```
int h, i;
void B(int w) {
        int j, k;
        i = 2*w;
        w = w+1;
}
void A(int x, int y) {
        bool i, j;
        B(h);
}
int main() {
        int a, b;
        h = 5; a = 3; b = 2;
        A(a, b);
}
```

9.3 Parameters

- Definitions
  - An *argument* is an expression that appears in a function call.
  - A *parameter* is an identifier that appears in a function declaration.

E.g., in Figure 9.1

The call A(a, b) has arguments a and b.

The function declaration A has parameters x and y.

Parameter-Argument Matching

- Usually by number and by position.

  I.e., any call to A must have two arguments, and they must match the corresponding parameters' types.

- Exceptions:

  Perl - parameters aren't declared in a function header. Instead, parameters are available in an array @_, and are accessed using a subscript on this array.

  Ada - arguments and parameters can be linked by name. E.g., the call A(y=>b, x=>a) is the same as A(a, b)

9.4 Parameter Passing Mechanisms

- By value
- By reference
- By value-result
- By result
- By name

Pass by Value

- Compute the *value* of the argument at the time of the call and assign that value to the parameter.
- E.g., in the call A(a, b) in Fig. 9.1, a and b are passed by value. So the values of parameters x and y become 3 and 2, respectively when the call begins.
- So passing by value doesn't normally allow the called function to modify an argument's value.
- All arguments in C and Java are passed by value.
- But references can be passed to allow argument values to be modified. E.g., void swap(int *a, int *b) { … }

Pass by Reference

Compute the *address* of the argument at the time of the call and assign it to the parameter.

Example
Fig 9.3

Since h is passed by reference, its value changes during the call to B.

```
int h, i;
void B(int* w) {
        int j, k;
        i = 2*(*w);
        *w = *w+1;
}
void A(int* x, int* y) {
        bool i, j;
        B(&h);
}
int main() {
        int a, b;
        h = 5; a = 3; b = 2;
        A(&a, &b);
}
```

Pass by Value-Result and Result

- Pass by value at the time of the call and/or copy the result back to the argument at the end of the call.
  - *E.g., Ada's* in out *parameter can be implemented as value-result.*
  - *Value-result is often called* copy-in-copy-out.

- Reference and value-result are the same, except when *aliasing* occurs. That is, when:
  - *the same variable is both passed and globally referenced from the called function, or*
  - *the same variable is passed for two different parameters.*

Pass by Name

- Textually substitute the argument for every instance of its corresponding parameter in the function body.
  - *Originated with Algol 60 (Jensen's device), but was dropped by Algol's successors -- Pascal, Ada, Modula.*
  - *Exemplifies **late binding**, since evaluation of the argument is delayed until its occurrence in the function body is actually executed.*
  - *Associated with **lazy evaluation** in functional languages (see, e.g., Haskell discussion in Chapter 14).*

9.5 Activation Records

- A block of information associated with each function call, which includes:
  - *parameters and local variables*
  - *Return address*
  - *Saved registers*
  - *Temporary variables*
  - *Return value*
  - *Static link - to the function's static parent*
  - *Dynamic link - to the activation record of the caller*

9.6 Recursive Functions

- A function that can call itself, either directly or indirectly, is a recursive function. E.g.,

```
int factorial (int n) {
    if (n < 2)
        return 1;
    else return n*factorial(n-1);
}
```

self-call

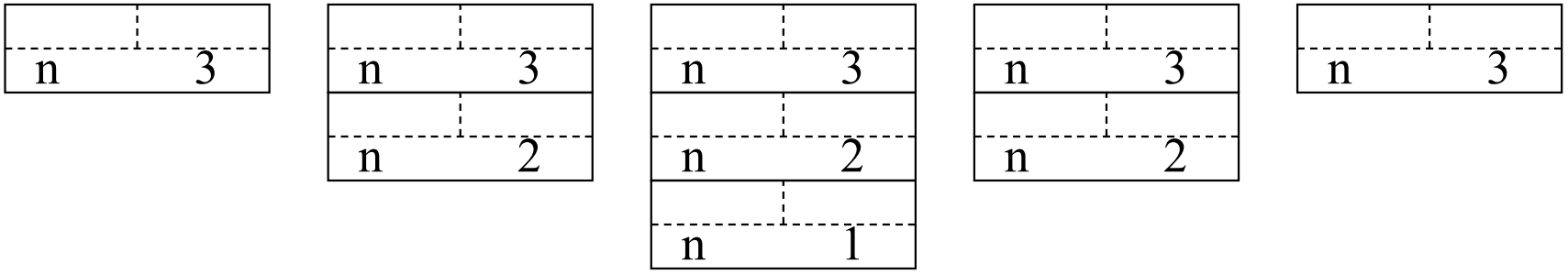
9.7 Run Time Stack

- A stack of activation records.
  - Each new call pushes an activation record, and each completing call pops the topmost one.
  - So, the topmost record is the most recent call, and the stack has all active calls at any run-time moment.

For example, consider the call factorial(3). This places one activation record onto the stack and generates a second call factorial(2). This call generates the call factorial(1), so that the stack gains three activation records.

Stack Activity for the Call factorial(3)

Fig. 9.7



First call

Second call

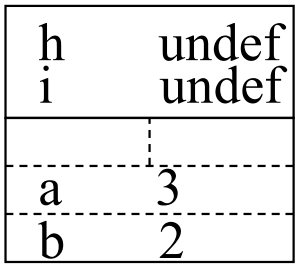
Third call returns 1

Second call returns 2*1=2

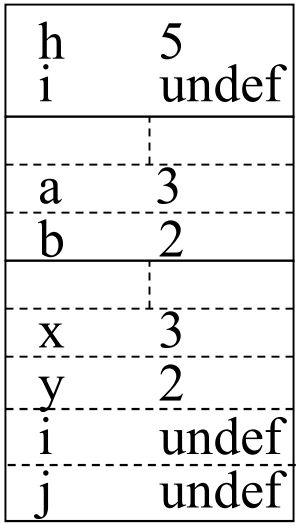
First call returns 3*2=6

Stack Activity for Program in Fig. 9.1

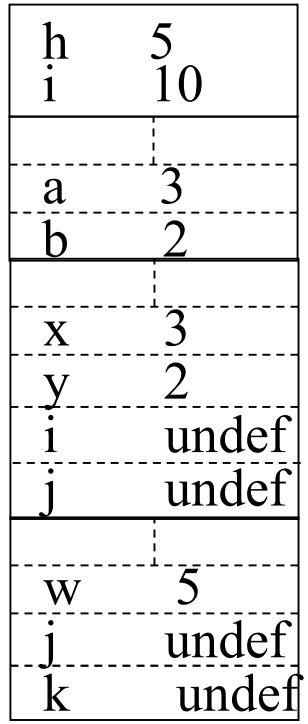
Fig. 9.8 (links not shown)



Activation of main



main calls A



A calls B